Introduction to the Canadian Space Environment Program

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Historical Perspective

- Ground-based study of geomagnetism and aeronomy an uninterrupted theme since 1840's.
- Canada was an early entry in the space race (3rd country to have flown a satellite), and this has given it a long history in space experiments
- Some fields remain strong, e.g.,
  - interferometer thermospheric wind observation
  - fast, global auroral imaging
  - Low-energy particles in near-Earth magnetosphere

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Current State

- Research Capacity in Space Plasma Physics
  - 7 universities, 3 government labs. ~30 permanent scientists, about an equal number of soft-money positions, and another equal number of PDFs and graduate students
  - Small but efficient support/technical infrastructures distributed among groups, in radio, optical, particle detector, and high-performance computing and data assimilation
- Smallness has led to a collaborative and complementary culture; conducive to consensus.

Role of CSA

- Has the legislated mandate on space since 1990
- Has a Space Environment budget under the Earth and Environment Service Line
- Is pursuing funding partnership and harmonization with NSERC, CFI, NRCan, NRC, and some Provinces
- Is working closely with the community to
  - Develop national collaborations for larger experiments
  - Develop areas of excellence, instead of pursuing a broad agenda

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CSA Strategy

1. Build a national consensus on program and program leadership
2. Define and implement a National Science Program
3. Pursue international collaborations to expand on 2, viz.,
   - ILWS as the general gateway (inter-agency)
   - opportunity-driven projects (among scientists, with agency support, e.g., THEMIS)
   - possible partnership with smaller space agencies to pursue low-cost and cost-sharing missions

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Specifically on ILWS

- CSA would like to
  - Contribute to the framing of the ILWS program so that Canadian scientists can participate fully
  - Use the national program as Canada's first and core contributions
  - Identify ILWS opportunities to define and develop new Canadian projects and contributions.

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Background on Opportunity

- Earth and Environment was identified as the top CSA priority
- CSA is pursuing a Small Satellite strategy (reuseable common bus design and 1 small/micro satellite launch per year)
- Space Environment can expect regular small-class mission opportunities (at 4-5 year interval)
- ILWS and its relevance to Canada will have a significant influence on the success of the above

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Existing Canadian Programs

- Overall Theme:
  - Microphysics @ geospace/atmospheric interface
  - Integrated ground multi-instrument array with multiscale capability (1-1,000 km)
- Two national collaborative projects have emerged:
  - Enhanced Polar Outflow Probe (ePOP) for the study of wave-particle interactions associated with mass loss from the polar ionosphere
  - Geospace Monitoring, an integrated ground-based array, five times as large as CANOPUS

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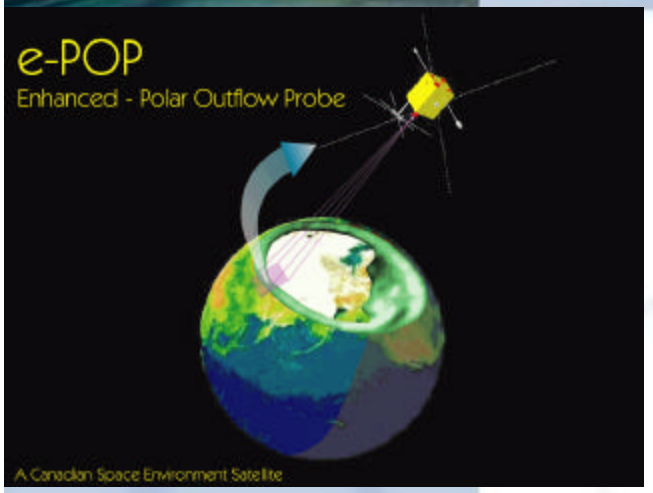

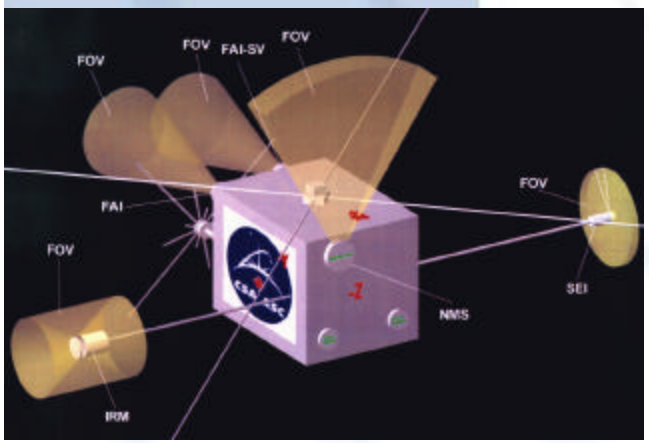

ePOP

- Phase A to be completed by March 03 (launch ~05/06)
  - A one-year small satellite mission in an inclined (~70º) elliptical (~300×2000 km) polar orbit
  - Seven scientific payloads
  - Primary science objective: Acceleration of ion outflow and its effects on neutrals
  - Secondary science objective: Initial work on ionospheric tomography through space-ground radio propagation

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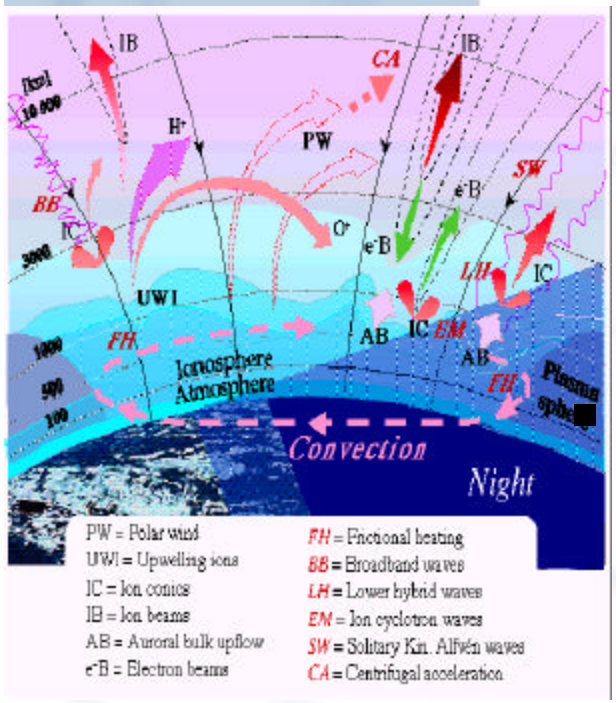
ePOP Particle Physics



- Micro-physics @ ~10 m scale, by measuring
  - Ion distribution between 1 and 100 eV and 1-40 amu @ 10 ms resolution
  - Electron distribution between 2 and 200 eV @ 10 ms resolution
  - Neutral species distribution
  - Fast auroral imager

Science Questions

- How are charged particles accelerated by ionospheric waves?
- How strongly do accelerated ions drag neutrals upward?
- The ionosphere as a source of magnetospheric particles
- New 'collisionless physics', if outflowing ions were found to interact strongly with neutrals

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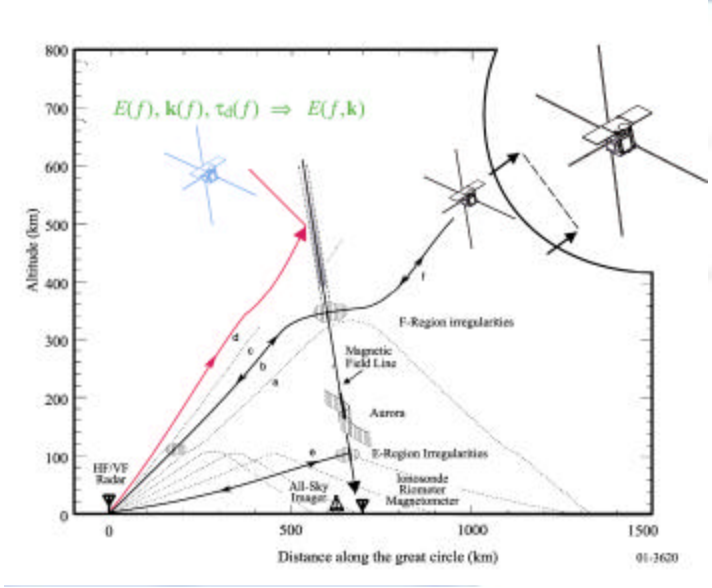
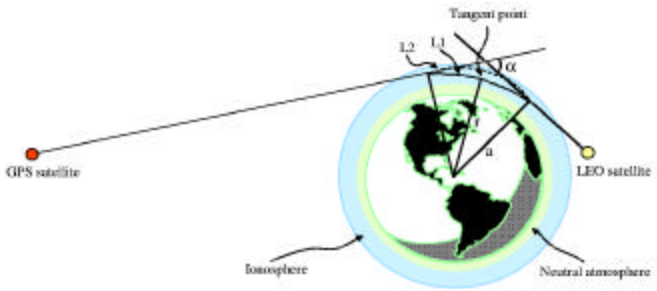
ePOP Radio Physics





- 100-30 kHz: local VLF waves
  - Help identify the acceleration mechanism
- MHz: wave propagation to s/c from ground radars and ionosondes
- GHz: GPS occultation and beacon
  - Tomography of ionosphere

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Geospace Monitoring

- Is an integration of all Canadian ground-based experiments, including CANOPUS
  - Solar radio monitoring
  - Enhanced (4×) CANOPUS magnetometers
  - NORSTAR auroral imaging array
  - Canadian SuperDARN and CADI
  - Center for Data Assimilation and Modeling
  - Canadian Space Weather Forecast Service
- CSA is aiming for real-time data delivery from >70 instruments in the array – space/w utility

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Geospace Monitoring

- Remote sensing > in-situ in discerning structures and in coverage scale
- Integrated Geospace Monitoring functions like a multiple-instrumented s/c, in terms of science cohesion and unity
- Most useful in
  - Dynamics of structures (e.g., storm/substorm relation)
  - Energy coupling across scales (e.g., s-storm onset)
  - Global energy circulation
  - Characterization of global wave distribution (mHz-Hz)

Solar Radio Monitoring

- Daily monitor of solar energy output
  - Though not matching the detail of more recent Sun-observing techniques, is more widely used and inexpensive to operate
  - Has over 50 years of data for climatological analysis, unmatched by s/c data
  - Canada is the sole producer of the data

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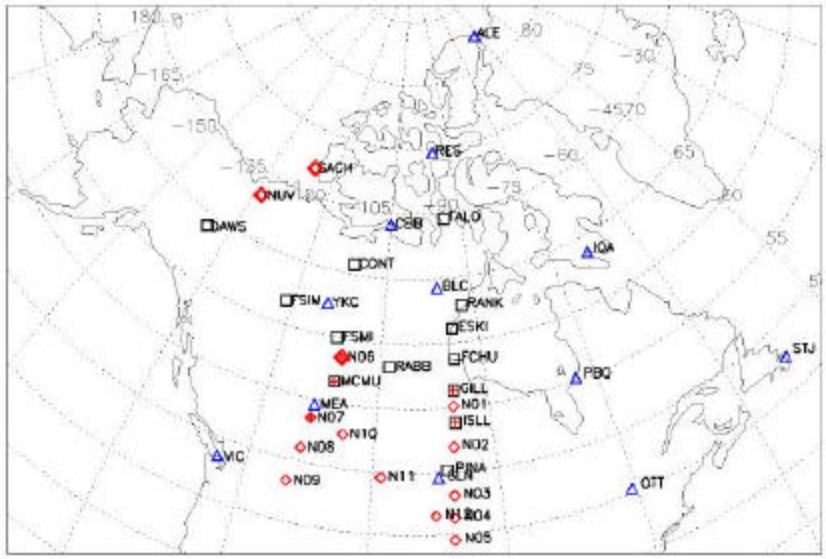
Enhanced Magnetometer Array



□ CANOPUS magnetometer
△ NRCAN magnetometer
◇ Proposed new fluxgate magnetometer site
+ Proposed new pulsation magnetometer
◇ Piggy back site

- Global magnetospheric waves and derivative information
  - New array has nearly 50 magnetometers, as opposed to CANOPUS's 13
  - Two complete chains for comprehensive MLT comparison and plasmasphere to psbl coverage
  - Much improved co-coverage with other instruments

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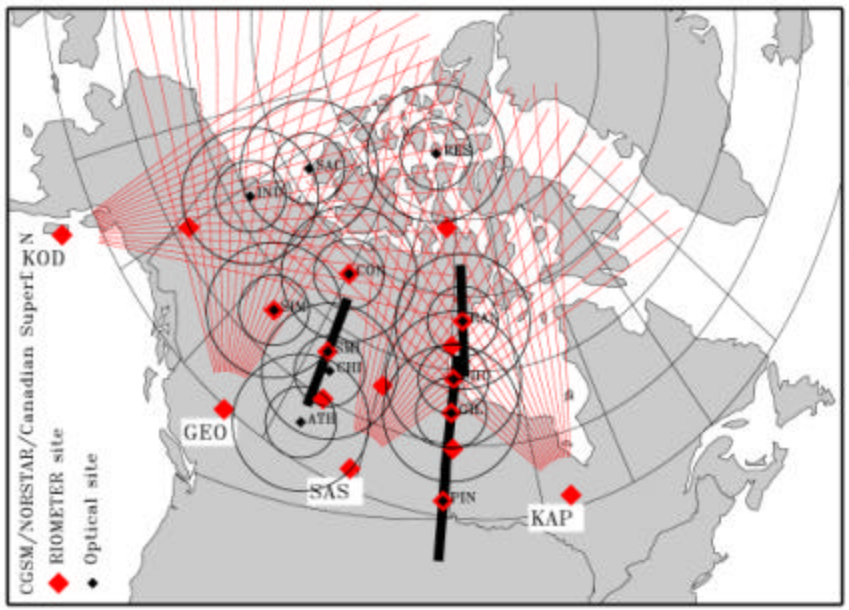
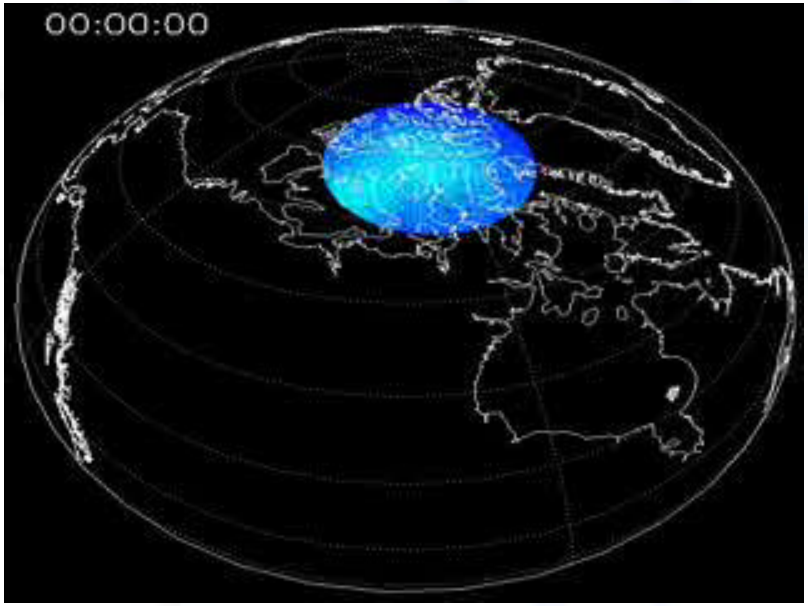
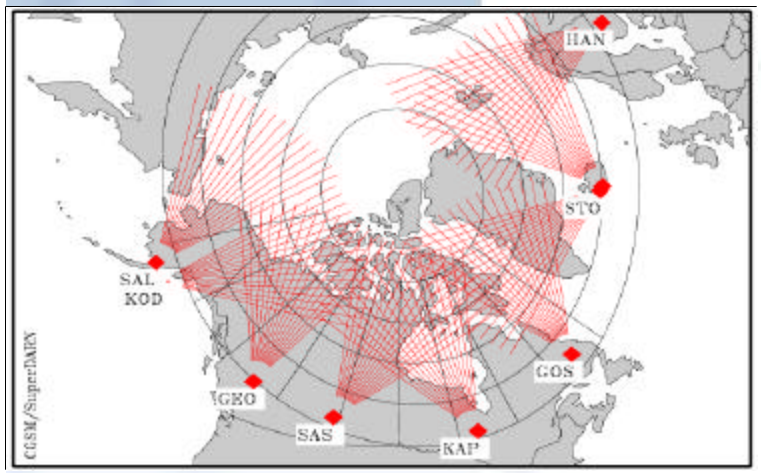
Ground-based Imaging





- NORSTAR will cover most of Canada with 10 all-sky imagers. On the right is a foretaste from 3. The goal is to use the precipitation pattern to remote-sense magnetospheric structures and dynamics

Canadian SuperDARN/CADI



- Global energy circulation
  - 4 of the 9 northern radars are based in Canada
  - U. Saskatchewan is the data copy center and operation schedule manager
  - Nine ionosondes @ polar cap boundary to complement radars
  - Uncompressed SuperDARN data (2.7 GB per site per day) can be used for tracing meteors (hence neutral motions)

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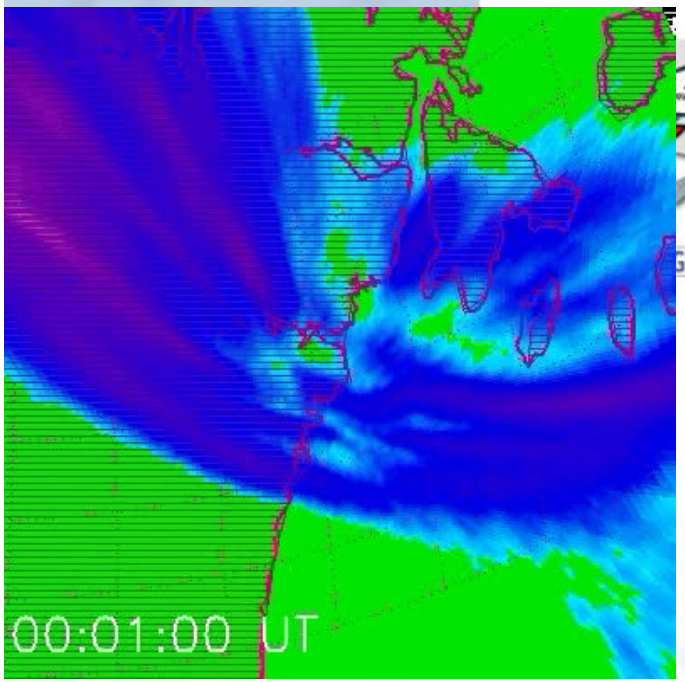
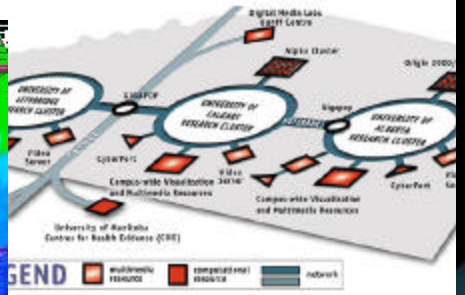
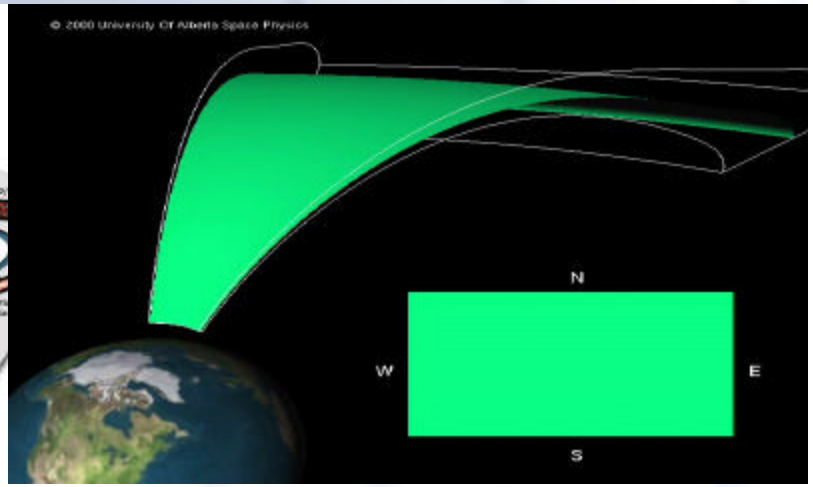
Data Assimilation and Modeling







- CSA has full access to a major CFI funded HPC and data grid facility for global-multiscale modeling and TB-level online data storage and manipulation.
- Integration of this element into Geospace Monitoring provides a fast track for Data (left)-Theory (right) Convergence

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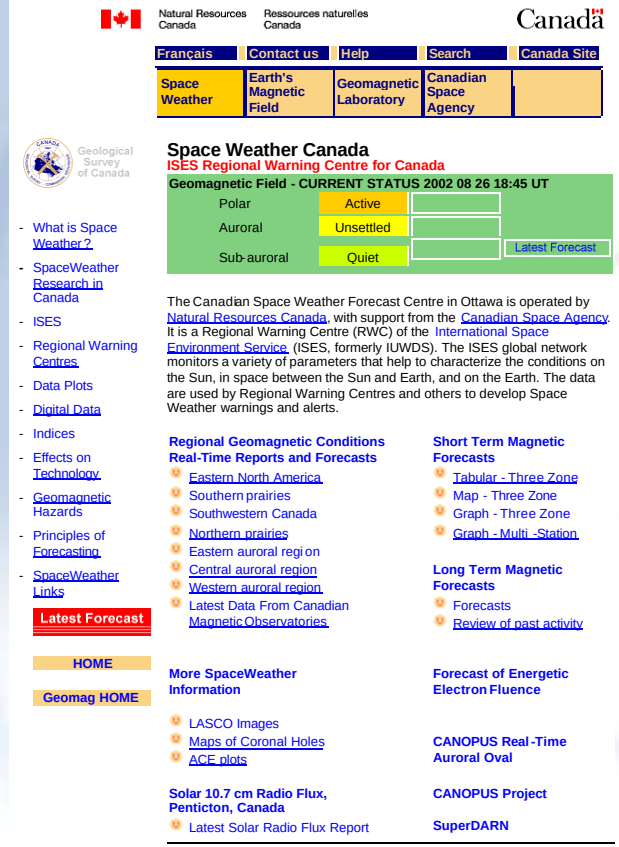
Canadian S/W Forecast Service



- Operational web-based srvc (www.spaceweather.ca)
  - Supported by NRCan and CSA
  - 90,000 service requests/hits per year
  - Client services for power, pipeline, and commsat operators

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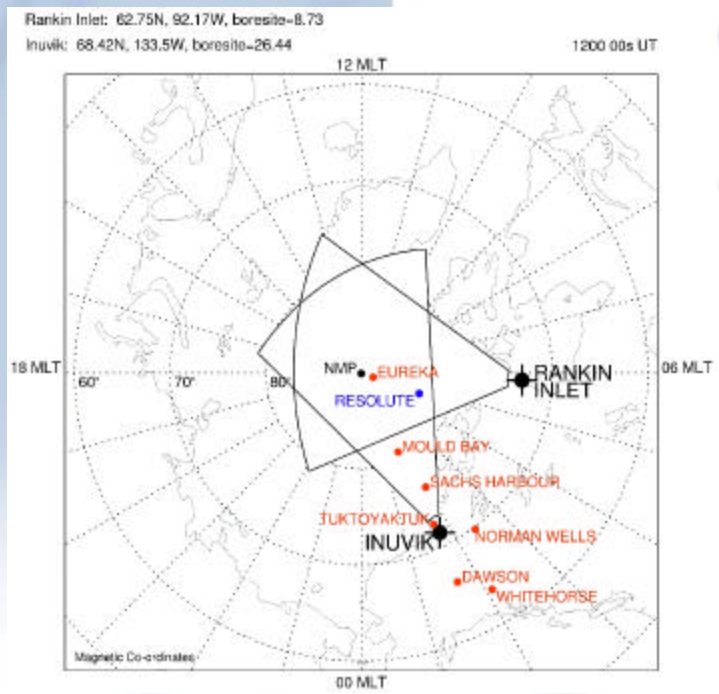
Potential ILWS Opportunities

- Principles
  - Consistent with overall Agency strategy
  - Consistent with available resources
  - Participation by a significant # of Canadian Scientists
- Themes (under discussion/incomplete list)
  - Small Sat constellation for ionospheric tomography and stereoscopic measurement of sources and sinks
  - A major int'l initiative for polar cap study

Options in Space

- Canada makes a s/c contribution to the Ionospheric Mapper constellation?
- Canada, along with smaller agencies, considers a complementary constellation?
- Canada negotiates with partners to participate in larger missions through payload/hardware contribution?

Options on the Ground



- Is there an international desire to make polar cap the next target of ground-based research?
- If yes, Canada can consider the construction of PolarDARN as part of an int'l initiative
- Canada and the Scandinavia are contra-located (~12 h MLT difference). A coordinated program offers interesting potentials.

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Opportunity-driven Collaborations

- THEMIS (MIDEX Phase A)
  - 5 microsat constellation for study of substorm timing
  - Conjunction strategy based on alignment with Canadian ground array
  - Project calls for additional ground instruments in Canada
- Similar ILWS opportunities will be positively received by the CSA

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General Comments

- ILWS should be more than an information exchange and should have a carefully formulated scientific agenda (i.e., mission statement)
- ILWS should have a common mission architecture (the NASA LWS architecture is a good start point for discussion)
- Ground-based science should be an integral and visible part of the mission architecture (e.g., an element on equal footing with the Ionosphere Mapper and Radiation Belt Mapper of NASA LWS Geospace Network)

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General Comments

- Major ILWS tasks can be modularized and their definition/development led by different agencies in the ILWS context
- ILWS could consider issuing a common set of international ILWS AOs, so that
  - Each or several collaborating agencies can select projects based on overarching goals/themes
  - Synergy among partners can be maximized by bringing timing and complementarity in line
  - "Sovereignty" an issue? (Most eggs in the ILWS basket)

General Comments

- Integrated data approach is the path for major breakthroughs, as info/data technology today has made it possible to contemplate the unthinkable 10 years ago.
- ILWS should adopt a common data scheme, with
  - A common data policy on access, use, and rights
  - A common ILWS-wide Data Portal to give users a basic level of access under a common standard
  - Regional or national data nodes
  - A voluntary depository for value-added products or value-generating tools

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Summary of CSA inputs

1. Make existing national programs part of the ILWS ramp-up phase (present to 2007)
2. In addition to 1, develop new Canadian projects based on ILWS themes befitting Canada
3. Subject to agreement by partners, make resources and personnel available to help coordinate the development of appropriate ILWS program modules (e.g., ground-based network)
4. Subject to agreement by partners, fund and support a Canadian regional data node as part of the ILWS Data Portal

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Some Afterthoughts

- Momentum is important, therefore
  - A series of carefully formulated actions should come out of this meeting
  - An agreement on general issues as soon as possible (preferably this meeting)
  - WG and/or appropriate definition teams meet regularly to generate agreements and results
  - Getting the scientific community involved early by forming a science advisory board.